System and Method of Determining Short Range Distance Between RF Equipped Devices

FIELD OF THE INVENTION

[0001] The present invention relates to a system and method of determining whether two electronic devices are within close proximity of each other. More specifically, the present invention relates to a system and method of determining whether two electronic devices engaged in an electronic financial transaction are within close proximity of each other.

BACKGROUND OF THE INVENTION

[0002] A wireless portable communications device such as a mobile phone is equipped to transmit and receive data or voice via a cellular network and can also be equipped to exchange digitized data, which can represent speech or voice, via a short range radio link.

[0003] Various proposals for using mobile phones, RF equipped personal digital assistants (PDAs), or any other portable RF equipped communication device for that matter, as means to conduct financial transactions are being developed.

[0004] The basic idea is that a portable wireless communication device can communicate an electronic token representative of monetary value to another device suited to receive such an electronic token. The portable wireless communication device may be a mobile phone equipped with suitable security devices and software, and it communicates with a device, which may be a Point-of-Sale (POS) terminal or kiosk equipped with a short-range radio interface unit.

[0005] In particular, when a POS device attempts to communicate with a portable wireless communication device belonging to a customer standing in line, for instance, it is a useful security check for the portable wireless communication device to be able to verify

that the signal it is receiving is from a nearby source, i.e. the POS device, and not from a more remote and perhaps fraudulent source.

[0006] What is needed is a system and method for verifying the proximity of a portable wireless communication device to a POS device. By ensuring that the two devices are within a certain proximity, it reduces the possibility of a fraudulent transaction occurring.

SUMMARY OF THE INVENTION

[0007] In an application where it is desirable to know the approximate distance between communicating devices employing a short range radio link, one device transmits a digitized data message using the short range radio link followed by digital data representing a digitized acoustic signal, such as a tone. Simultaneously, or with a predetermined time delay, the transmitting device emits an acoustic version of the same signal using an acoustic transducer such as a loudspeaker. The receiving device receives the data message and the digitized acoustic signal via the short range radio link and receives the acoustic version of the signal via a microphone, which converts the acoustic signal to a second digitized version of the acoustic signal.

[0008] Digital signal processing circuits then correlate the second digitized signal received acoustically with the digitized acoustic signal received over the short range radio link to determine a time difference of arrival between the two signals. The time difference is corrected for any predetermined delay(s) between the radio and the acoustic signal emissions at the transmitter and predetermined processing delay(s) in the receiver. Once a corrected time delay is determined, the receiving device can determine its distance from the transmitting device using the difference between the speed of sound and the speed of radio propagation.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] **FIGURE 1** is a flowchart that describes a method of measuring the distance between a pair of compatible RF equipped devices.

[0010] **FIGURE 2** illustrates a system arrangement according to the present invention.

[0011] **FIGURE 3** illustrates a block diagram of the RF components and processing occurring within a radio-acoustic interface unit and a personal communications device.

[0012] **FIGURE 4a** illustrates a two-tone ranging waveform suitable for use with the present invention.

[0013] **FIGURE 4b** illustrates a tone burst ranging waveform suitable for use with the present invention.

DETAILED DESCRIPTION OF THE INVENTION

[0014] **FIGURE 1** is a flowchart that describes a method of measuring the distance between a pair of compatible RF equipped devices according to the present invention. Initially, an RF link between two compatible devices is established **102**. For purposes of illustration, one device shall be referred to as a point-of-sale (POS) device while the other device shall be referred to as a portable wireless communication device. A particularly suitable RF link for purposes of the present invention is the Bluetooth™ protocol since it is specifically designed for short range wireless communications between similarly equipped devices. The Bluetooth™ protocol allows Bluetooth™ equipped devices to passively sense one another when one device nears another. Upon sensing the existence of another Bluetooth™ equipped device, a handshake occurs and the two devices may then exchange data.

[0015] Upon establishment of an RF link between the POS device and the portable wireless communication device, the POS device emits **104** an audio signal via a speaker while simultaneously (or nearly simultaneously) transmitting **106** a digitized version of the audio signal. The portable wireless communication device receives both

the emitted audio signal **108** (via a microphone) and the transmitted signal **110** (via an RF module). Both signals are then passed to a processor within the portable wireless communication device for processing. The processing includes digitizing the received audio signal from the microphone and comparing **112** it to the received signal from the RF module. If the signals match, then the portable wireless communication device determines the time delay between the arrival of the signals **114** after correcting for any predetermined transmission or reception delays. The time delay is then used to calculate the distance between the POS device and the portable wireless communication device **116**. This is a relatively simple step since the speed of sound and the speed of radio wave propagation is known. Distance *(d = v*t)* can be solved for using simple algebra since time and velocity (speed) are known.

[0016] FIGURE 2 illustrates an arrangement for practicing the present invention. A point-of-sale (POS) device **202** is connected to (or houses) a radio-acoustic interface unit **204**. Radio-acoustic interface unit **204** is able to automatically transmit a radio signal via antenna **210** as well as emit an acoustic signal via loudspeaker **206** and pick up an acoustic signal via microphone **208**. Similarly, a portable wireless communication device **212** is able to automatically receive a radio signal via antenna **122**. Portable wireless communication device **212** is also able to transmit a radio signal via antenna **218** as well as emit an acoustic signal via loudspeaker **214** and pick up an acoustic signal via and microphone **216**.

[0017] The short range radio link between antennas **210** and **218** may be a bi-directional radio link using the Bluetooth™ standard, which employs Time-Division-Duplex alternate bursts in alternating directions and pseudo-random frequency hopping to provide interference tolerance from other devices operating in nearby frequencies. The Bluetooth™ short range link is able to exchange digital messages between attached processors as well as digitized

audio data. The digitized audio data is coded as 64 kilobit *Continuously Variable Slope Delta* (CVSD) modulation which provides more graceful degradation in the presence of errors than 64 kilobit pulse code modulation (PCM). Audio signals may first be available as PCM, but are converted to CVSD for transmission and reconverted to PCM upon reception. PCM audio signals may also be converted to analog audio signals and vice-versa with the aid of standard PCM Coder/Decoder (CODEC) circuitry.

[0018] Thus, radio-acoustic interface unit **204** can emit a Bluetooth™ radio signal bearing digital acoustic information and can emit an acoustic signal from loudspeaker **206** based on the same acoustic information. Portable wireless communication device **212** can receive a Bluetooth™ radio signal bearing digital acoustic information and can simultaneously (or nearly simultaneously) receive an acoustic signal via microphone **216** based on the same acoustic information, and convert both to a common PCM form. A processor within portable wireless communication device **212** receives both PCM forms of the same acoustic information and correlates the two PCM sample sequences to determine a relative phase or delay. The relative phase or delay may then be converted to a distance if desired before being compared to a threshold to verify the proximity of radio-acoustic interface unit **204**, thus guarding against an undesired response to signals from a more remote source.

[0019] Referring to **FIGURE 3**, A control processor **302** which may reside in a POS device **202** or be part of radio-acoustic interface unit **204** is attached to a Bluetooth™ module **304** and antenna **210**, and a PCM CODEC **306**. The output of PCM CODEC **306** is amplified by audio amplifier **308** to drive loudspeaker **206**. A microphone **208** can also be included in order to pick up audio acoustic signals.

[0020] Similarly, portable wireless communication device **212** comprises a processor **310** connected to a Bluetooth™ module **312** and a PCM CODEC **314**. PCM CODEC **314** converts analog audio signals from a

microphone **216** to digital form. An amplifier **316** and loudspeaker **214** combination is also included for emitting audio acoustic signals.

[0021] The Bluetooth™ equipped devices have the ability to exchange initialization messages in order to discover each other's presence and establish an ad-hoc link according to the Bluetooth™ published standard. The ad-hoc link can comprise the transmission of real-time digital audio signals with a fixed delay. The fixed delay is achieved by not employing *Acknowledgement Request* (ARQ) overhead signaling or packet retransmission for corrupted speech packets. Instead, such errors are simply tolerated. Other digital overhead messages not tolerant of such errors, however, utilize ARQ to guarantee error-free delivery.

[0022] The present invention establishes a digital audio link between a processor **302** within radio-acoustic interface unit **204** and a processor **310** within portable wireless communication device **212** so that PCM audio samples originating in one processor are conveyed to the other with a known delay. When the Bluetooth™ link is established, the same PCM audio samples are output from processor **302** to a PCM CODEC **306** and are then amplified, if necessary, by amplifier **308** and emitted as an acoustic signal from loudspeaker **206**. The acoustic signal is picked up by microphone **216** within portable wireless communication device **212** and converted to PCM samples by CODEC **314** and input to processor **310**.

[0023] Thus, processor **310** receives the same audio signal by a Bluetooth™ module **312** and by the acoustic link. The former has propagated from antenna **210** to antenna **218** at the speed of light while the latter has propagated from loudspeaker **206** to microphone **216** at the speed of sound. By comparing the PCM samples received at processor **310** via the radio route and the acoustic route to determine a relative time delay, the distance between the radio-acoustic interface unit **204** and portable wireless communication device **212** can be determined.

[0024] If, for instance, 8 kilosamples per second PCM is used, and the relative delay is determined with a resolution of 1 PCM sample or 125μS, that corresponds to a distance resolution of approximately 1.5 inches.

[0025] To resolve ambiguity, the acoustic signal can be constructed as a multi-tone signal or as a series of tones. A single 1KHz tone has an ambiguity of multiples of one foot approximately, while a 1.1 KHz tone would have an ambiguity of multiples of 13.2 inches approximately. By using both tones either together or in sequence, the ambiguity distance can be increased by a factor of 10.

[0026] Another method to resolve ambiguity is to use tone bursts and to compare the rise and fall envelopes of the tone bursts to determine a coarse delay, while using the tone period to determine a fine delay. **FIGURES 4a** and **4b** illustrate that these waveform ambiguities may be resolved by comparing the larger features of the beat envelope of the two-tone signal or the envelope of the tone burst while resolution is obtained by comparing the zero crossings of the tone waveform, for example.

[0027] Both the radio-acoustic interface unit **204** and the portable wireless communication device **212** can be calibrated to determine fixed delays. The radio-acoustic interface unit **204** can be operated with a "reference portable device" of standard delay and deviations from a standard delay would be determined and programmed into memory in order to correct manufacturing spreads. Likewise, portable wireless communication device **212** can be operated against a reference portable device to determine deviation from a standard delay which would also be programmed into memory. If necessary, portable wireless communication device **212** and the radio-acoustic interface unit **204** can exchange such calibration factors in non-real time via Bluetooth™ packet overhead messages.

[0028] Once the distance between the portable wireless communication device **212** and the radio-acoustic interface unit **204** has been determined, decisions pertaining to transactions between the two

devices can be processed. For instance, if the distance is greater than a threshold value, then further processing can be aborted. Such processing could include terminating a proposed financial transaction if the distance is greater than a threshold value.

[0029] The short-range radio-acoustic determination system and method described herein may also be applied to the reverse direction, i.e. when the POS device wishes to verify the proximity of a portable wireless communication device.

[0030] The invention described may have applications outside of e-commerce that can be developed by a person skilled in the art using the above teachings. Such adaptations are considered to fall within the spirit and scope of the invention if described by any of the attached claims.

[0031] The present invention is described herein in the context of a portable wireless communications device. As used herein, the term "portable wireless communications device" may include a cellular radiotelephone with or without a multi-line display; a Personal Communications System (PCS) terminal that may combine a cellular radiotelephone with data processing, facsimile and data communications capabilities; a PDA that can include a radiotelephone, pager, Internet/intranet access, Web browser, organizer, calendar and/or a global positioning system (GPS) receiver; and a conventional laptop and/or palmtop receiver or other appliance that includes a radiotelephone transceiver. Portable wireless communications devices may also be referred to as "pervasive computing" devices.

[0032] The present invention may be embodied as cellular communication systems, methods, and/or computer program products. Accordingly, the present invention may be embodied in hardware and/or in software (including firmware, resident software, micro-code, etc.). Furthermore, the present invention may take the form of a computer program product on a computer-usable or computer-readable storage medium having computer-usable or computer-readable

program code embodied in the medium for use by or in connection with an instruction execution system. In the context of this document, a computer-usable or computer-readable medium may be any medium that can contain, store, communicate, propagate, or transport the program for use by or in connection with the instruction execution system, apparatus, or device. The computer-usable or computer-readable medium may be, for example but not limited to, an electronic, magnetic, optical, electromagnetic, infrared, or semiconductor system, apparatus, device, or propagation medium. More specific examples (a nonexhaustive list) of the computer-readable medium would include the following: an electrical connection having one or more wires, a portable computer diskette, a random access memory (RAM), a read-only memory (ROM), an erasable programmable read-only memory (EPROM or Flash memory), an optical fiber, and a portable compact disc read-only memory (CD-ROM). Note that the computer-usable or computer-readable medium could even be paper or another suitable medium upon which the program is printed, as the program can be electronically captured, via, for instance, optical scanning of the paper or other medium, then compiled, interpreted, or otherwise processed in a suitable manner, if necessary, and then stored in a computer memory.

[0033] In the following claims, any means-plus-function clauses are intended to cover the structures described herein as performing the recited function and not only structural equivalents but also equivalent structures. Therefore, it is to be understood that the foregoing is illustrative of the present invention and is not to be construed as limited to the specific embodiments disclosed, and that modifications to the disclosed embodiments, as well as other embodiments, are intended to be included within the scope of the appended claims. The invention is defined by the following claims, with equivalents of the claims to be included therein.